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ABSTRACT

This paper discusses methodological issues and strategies that underlie the development of expert software systems that provide research assistance to school practitioners of action research. The following key issues related to the development of expert systems software are examined: developing a knowledge base that represents research expertise; creating flexible development strategies and software environments; and addressing school research practitioners' special consultive needs. In conclusion, expert systems methodology for action research will be most effectively used in conjunction with an extended apprenticeship model, will reformulate how methodological principles are represented, and will improve the training of novice educational researchers. (LMI)

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SHORT PAPER

USING ARTIFICIAL INTELLIGENCE TECHNOLOGY TO SUPPORT ACTION RESEARCH IN SCHOOLS: METHODOLOGICAL STRATEGIES AND ISSUES[1]

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Abstract

Artificial intelligence methodology offers a potential means for insuring "real time" accessibility of consultive research expertise to school action research practitioners. Adopting perspectives based upon proven applications of artificial intelligence applications in industry, this paper discusses methodological strategies and issues that underlie the development of such software environments.

Action Research as a Setting For Professional Consultation

This paper reflects the view that action research is a type of applied research (Bogdan & Biklin, 1992) that happens to be conducted by those whose motivation is to directly experience its potential benefits. Thus, in schools, action research might be conducted by principals, teachers, administrators, or even by students in their own interest. In this sense, we recognize that action research necessarily has a perspective that is specifically "local" in emphasis. Yet, because we consider the goal of research the establishment of knowledge between as well as within settings, our feeling is that it is inappropriate to limit the implications of any research endeavor purposively (particularly those from action research) that otherwise might be generalizable simply because of the motivations of the researchers themselves. Rather, we feel that as a subset of research inquiry, action research must meet all standards of research practice that apply whenever a study is designed to allow conclusions to be reached, whether they are of theoretical significance, practical utility, or both.

Considering action research as a subset of research in general has an important utilitarian function in addressing the technical question of how to provide research assistance to inexperienced researchers, some of whom might be practitioners. This is because this assumption allows the same knowledge-domain that represents the core expertise of an idealized experienced researcher to serve as a basis for effective guidance across all research settings. This is not to say that all settings are identical, for they are not, but rather that they have much in common. Certainly, we recognize (along with those who conduct programmatic research in an area) that there are important nuances within substantively different areas of inquiry. Nevertheless, our concern here will be to address the question of providing general consultive assistance to research practitioners of limited experience. In this context, we feel it is sound to approach the question of providing such research assistance by assuming a common knowledge-base representing idealized research expertise whose availability is technologically engineered for researchers who have different degrees of experience and capabilities and who conduct research in various school settings.

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The Concept of an Expert System Consultant

The utilization of an expert system by a school (i.e., action) researcher is equivalent to an interactive consultation with a highly experienced human expert to gain assistance in addressing a research problem (e.g., What should I do to conduct research on this topic?, What should my research questions be?) or in solving a specific problem within a research study (e.g., Given the conclusions I want to make, how should I design my study?, Given my study, how should I measure the outcomes?). During such a consultation, the expert and school researcher would interact to describe the problem, clarify the specific details and constraints, and then specify the actions to be taken. In guiding the interaction, the expert's knowledge of research principles in conjunction with practical rules of thumb based upon extensive research experience would be linked to the school researcher's specific knowledge of the problem solution. As part of this process, the consultant would be able to answer questions explaining why certain information is needed, how various conclusions were reached, and how possible changes in the research setting (e.g., research questions, practical constraints) might require alternate solutions (i.e., what if questions).

Within an expert systems application, school researchers would obtain similar consultive assistance through expert systems software developed to emulate the competence of such an experienced human expert. Under conditions in which the availability of human experts is limited, the potential value of expert systems software is its' capability to deliver consultive expertise to an individual with a degree of frequency or level of depth that a human expert could not provide due to limited accessibility. In developing such software, the major logical requirements that must be addressed technically are the representation of research expertise (i.e., the knowledge-base), the specification of knowledge-processing mechanisms that control the linking of the knowledge to the specifics of the problem setting in order to identify appropriate courses of action (i.e., the inference engine), and the design of the interface through which the school researcher and software will interact.

An important step in the development of expert systems software is the selection of a software environment for building (and delivering) the system. Although any general purpose programming language, in principle, could be used, specially designed software development environments called "shells" are commonly used because they facilitate rapid prototyping and efficient system construction for a variety of methodological reasons. Among the most important is that, the architecture of the shells separates the "knowledge" component of the software from its other parts (e.g., user interface, management of consultive data, explanation facility, knowledge-processing/inference component). By using shells, developers of expert systems software become free to focus upon the encoding of expert knowledge that allows the software to emulate the performance of an expert rather than writing computer program(s) to implement all the various components of the system. Thus, the shell itself provides the developer with a supportive environment containing all of the tools needed to produce the system with the exception of the knowledge (that the developer inserts into the system) and the nature of the interface (about which the developer decides).

When encoding expertise into the shell software, a common form of knowledge representation consists of production rules in the form of IF/THEN statements through which actions (i.e., THENs) are tied to patterns of conditional information (i.e., IFs). With such knowledge-based rules entered into the software shell, the expert system is able to decide what actions to recommend for problem-solving during a consultation by querying the user regarding circumstances specific to a particular setting. By matching patterns of circumstances to patterns of production rule conditions (IFs) and by following logical chains of such rules, the expert systems software can focus upon obtaining relevant information (and ignoring irrelevant details) while determining a proper course of action. In turn, the actions recommended by the program provide guidance for the end-user.

The development of an expert system follows a general strategy for capturing human expertise that is commonly referred to as "knowledge engineering". First, one or more experts are carefully studied across a representative range of problem-solving applications. The purpose here is to determine what

the expert does, the conditions under which it is done, and obtain clarifying explanations from the expert as to why it is done. Second, the resulting expertise is represented in IF/THEN production rules (or a more advanced knowledge representation scheme) and input into the expert system shell. Third, the system is applied to a variety of representative problem situations, the results compared with those of experts, and the knowledge-base (e.g., production rules) modified as necessary. Fourth, the revision-test cycle is repeated until the software can emulate the consultive performance of the expert. And, last, the software is delivered for use after which it's performance in the field is monitored on an ongoing basis so that it can be regularly maintained (e.g., updated, improved). Although additional detail is beyond the scope of the present paper, Payne & McArthur (1990) describe the application of development strategies using a variety of expert system shells and a monthly trade magazine, AI Expert, regularly reviews expert systems software for popular microcomputer platforms (IBM, Macintosh).

Methodological Issues in the Development of Expert Systems that Support the Practice of Research

This section overviews key issues specifically relating to the development of expert systems software that would provide research assistance to school practitioners.

Developing the Knowledge-Base that Represents Research Expertise. Although textbooks on research methods provide an initial point for determining research expertise, they do not provide an adequate foundation for developing a research knowledge-base for the "knowledge-engineer." This is true for a number of reasons. First, recognizing Anderson's (1982) distinction, expertise must be represented as procedural knowledge (i.e., as actions that occur under patterns of conditions) in order to be usable in an expert system. In this regard, much of the knowledge in textbooks is in declarative form (i.e., knowledge about...) that, even with appropriate translations, is not detailed enough to represent the range of expertise needed by the practicing researcher. Second, the scope of expertise needed to conduct research is far broader than that encompassed by traditional textbooks in research methods. In effect, despite their value contributing to the knowledge-base in some areas (e.g., statistical analysis of data, aspects of experimental design, aspects of measurement procedures), textbooks as a whole are incomplete representations of the broad range of expertise required to conduct sound research.

Because textbook-based knowledge is of limited value, the full development of a research knowledge-base can only result from the analysis of the performance of experts working on a representative range of research problems. With this need in mind, Vitale (1993) has presented a scheme for classifying empirical research studies that could provide the basis for specifying the necessary problem-domain by reflecting the stages through which scientific knowledge naturally evolves. The resulting continuum then could provide sufficient structure in the form of a domain to facilitate the explication of categories of research expertise that focus on the following:

- establishing the existence of a phenomenon
- determining the conditions under which a phenomenon occurs
- relating the phenomenon to other phenomena
- establishing manipulatable conditions that determine the occurrence of the phenomenon
- developing theory in the form of the symbolic codification of a through d
- engineering technological applications that incorporate theory (considered as scientific knowledge)
- verifying the soundness of technological applications

Complementing this scheme, Vitale (1993) argued for mapping the interrelationship of various types of research perspectives (e.g., qualitative, quantitative, applied, theoretical, action, etc.) in terms of a two underlying elements: (a) an absolute distinction between experimental and non-experimental research in combination with (b) a continuum of research settings ranging from artificial (or laboratory) vs naturalistic.

From the standpoint of organizing research problems (and expertise), the idea that either experimental or non-experimental research (considered to allow qualitatively different forms of conclusions) may be conducted in either naturalistic or laboratory settings and the idea that the domain of all research (including the scheme above) is encompassed by these two classification dimensions has much to recommend it with regard to parsimony. In this spirit (after Sidman, 1960), this scheme considers all research as theoretical, with some theoretical research also being applied if it addresses behaviors having societal value; while (after Johnson & Pennypacker, 1980), the concerns of qualitative researchers are repositioned to fall within a broadened perspective having to do with measurement and scaling. In particular, from the standpoint of addressing the question of explicating the research expertise required for action research, Vitale's (1993) scheme implies that qualitative and quantitative research may be represented as part of a broader research perspective, and, thus, do not represent fundamentally different distinctions that would require different domains of expertise. Rather, this distinction is considered to denote sociological characteristics of researchers that are not encompassed within expertise in combination with methodological preferences (and styles) that can be incorporated into a common expertise domain. methodological styles that would be represented in expertise. In any case, whether Vitale's (1993) or an alternate scheme is used to represent the domain of research practice, the performance of expert researchers across the domain must be represented fully in the knowledge-base of the expert system in order for it to provide effective guidance through consultation. In this regard, textbooks on research methods are clearly inadequate in both breath and depth and some form of knowledge engineering strategies are necessarily required.

Flexible Development Strategies and Software Environments. Although the process for developing an expert system in general and the knowledge-base in particular has been presented as if it consists of a sequential series of discrete steps, in most cases it is not. Rather, the development of an expert system is much more of a "bootstrap" operation in which different parts of the development process interact with one another. This is because the knowledge of most experts consists of what are known as "ill-defined domains." As a result of what might be considered "true" expertise being very difficult to capture directly, the development of most expert systems emphasizes incremental prototyping (vs top-down design) as a development strategy in which increasingly larger parts of the system are implemented and evaluated until the final system is completed.

In following a prototyping strategy, the selection of a software development environment (e.g., shell) is critical since extensive editing and restructuring of the knowledge-base may be required at any point in the development process and since the size of the system cannot be determined in advance. Therefore, before initiating a project using a shell, it is important to evaluate the software environment in terms of these concerns and, if possible, talk directly to individuals (i.e., experts) who have prior experience developing the type of application that is being considered regarding these and other technical concerns (e.g., type of inference engine(s) supported, object-oriented knowledge structures). Although beyond the scope of this paper, some good expert systems shells to investigate for IBM microcomputer platforms running under Microsoft Windows 3.0 or above are Symbologic Adept, Goldworks III, Level 5 Object, and EXSYSS.

In many cases, the application domain, the associated expertise, and the needs of the end-user are so ill-defined that substantial preliminary development work must be done in order to clarify the consultive problem being addressed. Our feeling is that the question of providing consultive assistance to practitioners is clearly in this category. As a result, our present efforts in developing consultive research systems are pursuing the following strategy:

- an initial attempt to frame-out the domain of research and research expertise in a parsimonious and modular form

- an explication of the consultive needs of the school researcher having little research experience

- the use of a hypertext-type of software environment (e.g., Toolbook on the IBM platform) that allows some aspects of the potential knowledge base and the means of communication of information between software and user to be explored

- the initial prototyping of modular elements of the expert system using Symbologic Adept which provides unique visual programming environment in which procedures as sequences of activities can be represented directly

- the subsequent development of the system using a knowledge-based expert system (e.g., Goldworks III) that supports production rules as part of more advanced forms of integrated knowledge structures (e.g., frames, objects) and alternate forms of inference (e.g., backward chaining, forward chaining, hybrid models).

Overall, the adoption of the above strategy allowing for the use of a number of complementary software environments was based upon a number of considerations. First, a major underlying concern was the assumption that the explication of the research knowledge-base in conjunction with the needs of the school practitioner would likely involve substantial revision. This is simply due to the fact not all aspects of educational research methodology are well developed and the many areas that are well-developed do not always represent methodology in the form of the capabilities or procedures of which expertise consists. Second, some interactive field-testing is required to develop a workable interface model. This is far easier to do in a limited prototyping fashion using a hypertext environment such as Toolbook, before encoding complex forms of knowledge into an expert system shell.

The third consideration is important because we anticipate that an emphasis on modularity and the capability to integrate different software environments may facilitate the development effort and provide a more naturally-usable form of consultive software for school researchers. For example, during a consultation it might be natural for the user to browse and select different alternatives- a capability that is much easier to develop in a hypertext environment such as Toolbook. Or, some procedures might be developed most easily in Symbologic Adept because it is a form of shell that is designed to allow procedural knowledge to be naturally encoded. Or, more complex decisions involving the evaluation of sets of rules might be more readily developed through prototyping in a knowledge-based environment such as Goldworks III. In all cases, because each of the three environments can be integrated with the others, it is possible to integrate components of the overall system that have been developed through prototyping using different software environments. With this capability in mind, it is possible for an underlying prototyping strategy to be implemented efficiency.

Some Categories of Special Consultive Needs for School Research Practitioners. In identifying priorities associated with developing a consultive system, our particular interest is in focusing our efforts on the elements of the research process that experienced researchers emphasize (and which novices would be unaware) rather than those emphasized in textbooks. Although beyond the scope of this paper, some of these address broader aspects of research as inquiry such as (a) planning and implementing programmatic research (vs a single-study perspective), (b) strategies for networking with researchers of similar interests, (c) methodological approaches to qualitatively analyzing (e.g., observing, measuring, describing) both problem settings and treatment effects, (d) procedures for evaluating trends in research literatures and identifying (in specific areas) parallel research developments by non-educational researchers, and (e) standards for designing research given intended conclusions and for interpreting conclusions given design. Although in the formative stages, we feel that it is possible to develop expert systems software that provides at least minimal guidance for inexperienced researchers

in modular forms that could eventually be encompassed within a single program. At the same time, we also envision working to develop applications that support the more traditional research domains such as test development, statistical analysis, and traditional research design.

Implications of Expert Systems Methodology for Action Research

There are a number of important implications that follow from the application of expert systems technology to the problem of providing research support to school practitioners conducting action research. These are:

- The best use of such a system (and the best environment for development) would be in conjunction with the type of extended apprenticeship model described by Romance & Vitale (1993) in this symposium. Within this context, a major goal would be to capture different aspects of research expertise across the range of possible research applications as they are being supported. Although we can envision a useful collection of "stand-alone" expert systems emphasizing different aspects of the research process in a limited fashion, the overall concept of capturing all research expertise within a single software application having great levels of detail is unrealistic for the immediate future. Thus, we believe it is presently feasible to develop limited expert systems that school action researchers would find useful.

- It is clear to us that any serious attempt to represent expertise within the field of research would eventually lead to an improved reformulation of how methodological principles in research are represented. At the present time, just the application of parsimony alone would help eliminate the excessive terminology that professionals new to the field must face. However, even beyond verbal streamlining, any serious attempt to address the question of research methodology as procedural rather than declarative knowledge would have the effect of refocusing attention upon what the purpose of research is within the field and how it should be conducted.

- Finally, it is also clear that having the capability to develop knowledge-based systems that provide expert consultation would also have an effect on how researchers can be trained in general. Specifically, having the capability to represent research expertise across the domain of research practice could directly support the development of instructional models (e.g., Lawler, 1987) from the field of artificial intelligence, including intelligent (i.e., knowledge-based) tutoring systems in which students would receive computer-based guidance as they apply methodological skills to solve problems or engage in simulations to gain higher order research capabilities. In effect, the development of expert systems, even limited ones, would open the gateway for dramatic improvements in training novice educational researchers, both in and out of school settings.

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